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A New SST Climatology for the 1971-2000 Base Period and Interdecadal Changes of 30-Year SST Normal

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1. Introduction

Climate forecasts (monthly and seasonal) are generally issued in terms of anomalies and standardized anomalies relative to a 30-year normal: climatology and standard deviation. Due to the vast improvement of observations in recent decades and the non-stationarity of climate signal, the World Meteorological Organization (WMO) suggests to update the 30-year normal every 10 years. At the Climate Prediction Center (CPC) of NOAA, the official forecast for the tropical Pacific sea surface temperature (SST) index is issued as anomalies and standardized anomalies relative to the 1961-1990 base period. To make the base period compatible to that suggested by WMO, a new SST climatology for the 1971-2000 base period was constructed, and made available at the CPC's web site at http://www.cpc.noaa.gov/product/ predictions/ 30day/SSTs/sst_clim.html.

It has been suggested that the variance of the SST anomalies in the interannual band is high during 1880-1920 and 1960-90 and low during 1920-60 (Torrence and Compo 1998; Mestat-Nunez and Enfield 2001). From a prediction point of view, a change of standard deviation (STD, square root of variance) is as important as a change of climatology since STD is used to compute standardized anomalies. Here we examine the interdecadal changes of climatology and STD using both analyzed and in situ data sets, and using not only SST but also sea level pressure that is known to be highly related to SST on interannual time scales. The goal is to give a quantitative measure of the interdecadal changes of climatology and STD of SST in the past century, and to discuss the implications for climate forecasts.

2. Data

SST data sets include the 1-degree revised OI SST analysis by Reynolds et al. (2002). The original OI SST analysis uses global satellite and all available in situ data to produce a global 1^{o} SST analysis for the period in which satellite observations are available (November 1981-present, Reynolds and Smith 1994). In the revised OI analysis, a new sea ice to SST algorithm is introduced and the satellite bias correction is improved. The major improvement in the analysis occurs in high latitudes where local differences between the original and revised analysis can exceed 1^{o}C. For the period before 1982 when no OI analysis is available, we use the reconstructed historical SST (RSST) analysis by Smith et al. (1996). We also use the HADISST data set by Parker et al. (1999). HADISST is an improved SST analysis over the Global Sea-Ice and SST data set (GISST) (Rayner et al. 1996), and is computed monthly on a 1^{o} grid from 1870 to present. In compliment to the SST date sets, we use the sea level pressure at Darwin, Tahiti and Southern Oscillation Index for 1876-2001, downloaded from the web site of the Bureau of Meteorology Australia (BMA) (http://www.bom.gov.au/climate/current/soihtml.shtml).

3. SST climatology

The climatology for the 1971-2000 base period was constructed using the method of Smith and Reynolds (1998). The new climatology is a combination of two intermediate climatologies: a 2 degree in situ climatology developed from RSST for 1971-2000, and a 1 degree OI climatology derived from the revised OI SST analysis for 1982-2000.

Figure 1 shows the differences between the new climatology and that for the1961-1990 base period. The changes in the climatology are caused by changes in the base period as well as changes in the OI analysis. In the tropics and subtropics, the changes in the climatology are largely due to the changes in the base period, and are generally small with absolute differences usually less than 0.2˚C. However, in high latitudes the changes in climatology are due to the changes in the OI analysis alone. This is because there are insufficient in situ observations in high latitudes prior to 1982, and the climatology is based on the OI analysis alone (1982-2000). It is seen that the changes of climatology due to the changes in the OI analysis often exceed 1˚C.

4. Interdecadal changes of climatology and standard deviation

a. Climatology

In order to see the interdecadal changes of climatology and STD, a consistent SST analysis for all base periods is needed. Using RSST, we calculated the climatology and STD for the 1951-1980, 1961-1990 and 1971-2000 base periods. The differences of the climatology between consecutive base periods show a rather uniform warming of 0.1^{o}C in all the three tropical oceans, and a cooling of 0.2^{o}C in the north Pacific (Fig. 2). The changes in the north Atlantic are more variable, which is

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a cooling from 1961-1990 to 1951-1980 and a dipole SST with a cooling in high latitudes and a warming in mid-latitudes from 1971-2000 to 1961-1990. The decadal changes of SST in the north Pacific are related to the so called "Pacific Decadal Oscillation" (PDO) (Mantua et al. 1997). The decadal changes of SST in the Atlantic are associated with the "North Atlantic Oscillation" (NAO) (Kushnir 1994). Using HADISST, we obtained a similar pattern of interdecadal changes of SST.

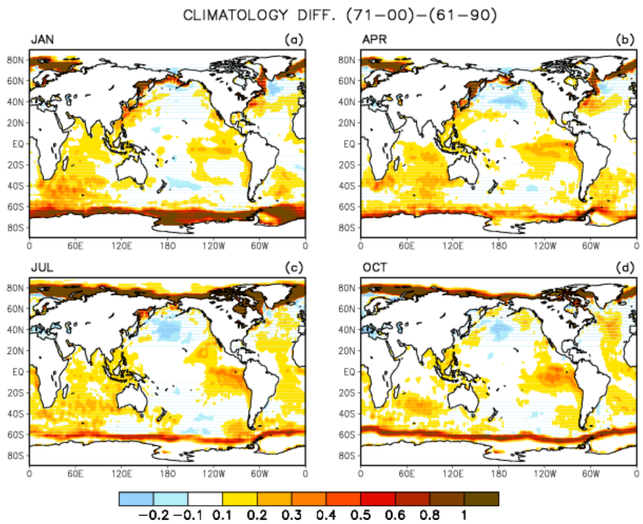

Fig. 1. Climatology difference (^{o}C) between the 1971-2000 and 1961-1990 base periods for (a) January, (b) April, (c) July, and (d) October.

B. Standard deviation (STD)

The annual mean STD of monthly SST anomalies derived from RSST shows an upward trend in the equatorial eastern Pacific since 1950 (not shown). This upward trend can be seen clearly in the STD of the SST anomalies in the NINO3.4 (5^{o}N-5^{o}S, 170^{o}W-120^{o}W) region (Fig. 3). Although the increase of the STD is rather uniform over the year, the percentage change of STD is most pronounced in the spring season when the STD is the smallest. This indicates that the forecast errors in the standardized anomalies could be as large as 17% in spring if the STD were not updated from the 1961-1990 to 1971-2000 base periods.

Torrence and Compo (1998) and Mestat-Nunez and Enfield (2001) also discussed the upward trend of interannual variance of SST in recent decades. They used the U.K. Meteorological Office GISST2.3 (Rayner et al. 1996) and the reconstructed historical SST by Kaplan et al. (1998). Since all the SST analyses utilized similar in situ and satellite data, we ask whether the increased variance is caused by the increased observations in recent decades. To address this question, we constructed a new historical SST analysis similar to RSST except in which the distribution of the in situ observations was held constant as that in 1950s (referred to as RSST_sparse hereafter). In fact, the NINO3.4 index derived from RSST_sparse agrees very well with that from RSST (not shown) and a similar upward trend of the STD of NINO3.4 is seen (Fig. 4).

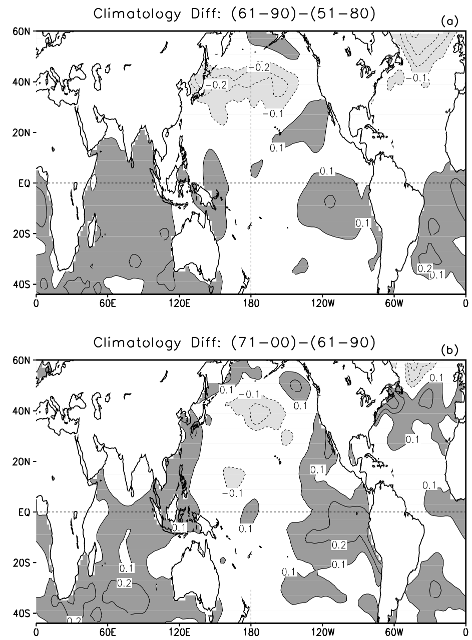

Fig. 2. Annual mean difference (^{o}C) of the climatology between (a) 1961-1990 and 1951-1980, and (b) 1971-2000 and 1961-1990 base periods. The climatology was derived from RSST. Contour interval is 0.1^{o}C. Values less than –0.1^{o}C and greater than 0.1^{o}C are shaded.

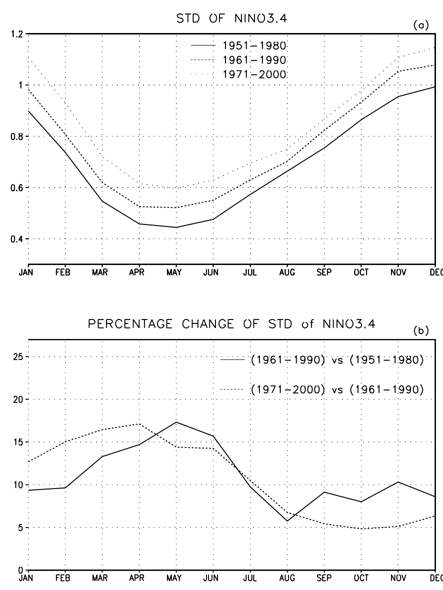

Fig. 3. Annual cycle of standard deviation (STD) (^{o}C) of monthly SST anomalies in the NINO3.4 (5^{o}N-5^{o}S, 170^{o}W-120^{o}W) region for the three base periods indicated in the figure. (a) STD, and (b) percentage change (%) of STD in consecutive base periods.

The STD of the sea level pressure at Darwin, Tahiti and Southern Oscillation Index (SOI shows a similar upward trend as that in SST (Fig. 5). However, the centennial long SST and sea level pressure data sets suggest that this upward trend is a part of an oscillation on centennial time scales. The results suggest that the variance of ENSO had undergone an oscillation: it decreased from 1890 to 1920, stayed flat and low during 1930-1940, and increased since 1950 (Fig. 4 and 5).

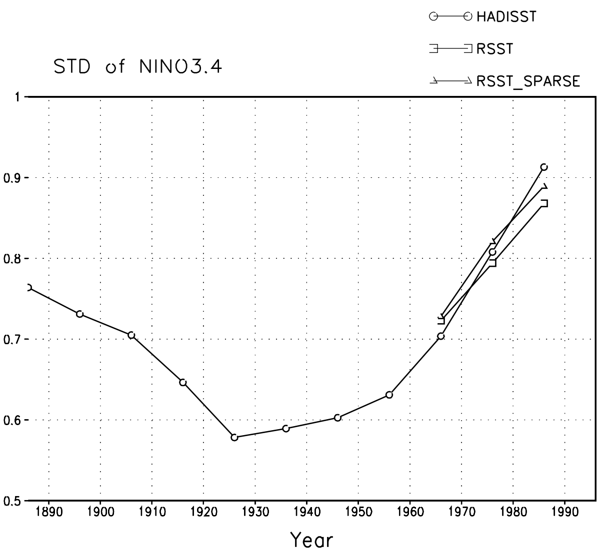

Fig. 4. Annual mean standard deviation (STD) (^{o}C) of monthly NINO3.4 index derived from HADISST, RSST and RSST_sparse (labeled in the figure) in 30-year base periods defined as 1881-1910, 1991-1920, ……, 1971-2000. The x-axis labels are at the centers of 30-year base periods.

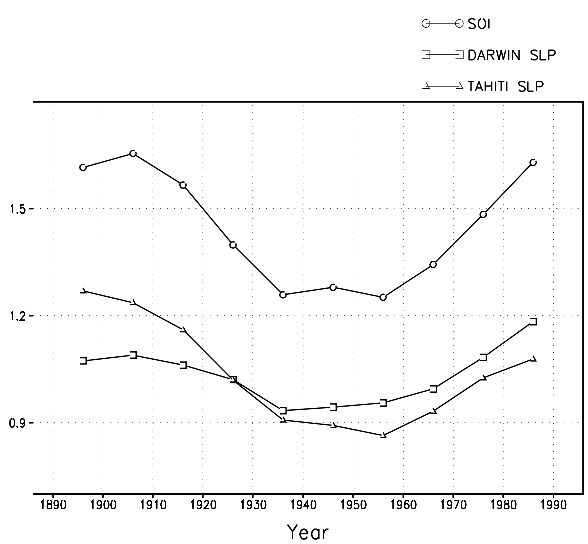

Fig. 5 Same as Fig. 4 except for the sea level pressure at Darwin and Tahiti, and Southern Oscillation Index that is the standardized anomaly of the mean sea level difference between Tahiti and Darwin.

5. Summary

In this paper we present a new SST climatology for the 1971-2000 base period. The change of the climatology between the 1971-2000 and 1961-1990 base periods is generally small with absolute differences usually less than 0.2^{o}C in the tropics and subtropics, while the changes in high latitudes exceed 1^{o}C due to the new ice algorithm introduced in the revised OI analysis (Reynolds et al. 2002).

A large part of the paper is focused on the interdecadal changes of SST climatology and standard deviation. For the three recent 30-year base periods, 1951-1980, 1961-1990 and 1971-2000, the annual mean of climatology shows a rather uniform warming of 0.1^{o}C in all the three tropical oceans and a cooling of 0.2^{o}C in the north Pacific for each consecutive base period (Fig. 2).

The STD of the NINO3.4 SST index has an upward trend since 1950 (Fig. 4). The percentage change of the STD is largest (17%) in spring when the STD is the smallest. This has an important implication for ENSO prediction since both anomalies and standardized anomalies of SST are issued as the official forecast at CPC. The centennial long SST data from the Hadley Center and the sea level pressure at Darwin, Tahiti and SOI suggest that this upward trend is a part of an oscillation on centennial time scales. Considering the mechanisms for the change of ENSO properties unclear, quantifying the changes of climatology and STD of SST in the past century is useful in monitoring climate changes and improving operational prediction of ENSO. Whether the change of ENSO intensity is related to global warming is another challenging question that remains to be answered in the future.

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